COUPLED CHANNEL STUDY OF $K^+\Lambda$ PHOTOPRODUCTION

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A coupled channel model with γN, KY and πN channels has been used to analyze the recent data of $\gamma p \to K^+\Lambda$. The non-resonant interactions within the subspace $KY \oplus \pi N$ are derived from effective Lagrangians using a unitary transformation method. The direct photoproduction reaction is obtained from a chiral constituent quark model with $SU(6) \otimes O(3)$ breaking. Missing baryon resonances issues are briefly discussed.

1. Introduction

Our knowledge of associated strangeness photoproduction processes has been greatly improved in recent years thanks to measurements performed at several facilities, JLAB [1,2], ELSA [3,4] and Spring-8 [5]. This database should serve to shed light on the properties of known, poorly known, and missing resonances.

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Our main aim in this contribution is to analyze the reaction $\gamma p \to K^+\Lambda$ making use of a coupled channel formalism. This work is an extension of Refs. [6, 7, 8] with improvements in the derivation of the meson-baryon intermediate states ($\pi N \to \pi N$, $\pi N \to KY$, and $KY \to KY$) and making use of the quark model of Refs. [9, 10] for the direct and resonance photoproduction of $K^+\Lambda$. A more detailed description of this investigation will be reported elsewhere [11].

The main physics under scrutiny are the properties of resonances. This analysis should improve our knowledge of the properties of more or less well known resonances and also possible manifestations of missing resonances, predicted by QCD-inspired approaches [12]. In our study a 3^{rd} S_{11}, 3^{rd} P_{13} and 3^{rd} D_{13} resonances are considered and their relevance is examined.

2. Theoretical model

A simple glimpse at the cross sections for meson photoproduction reveals that the pion photoproduction process is orders of magnitude larger than for strange photoproduction [13]. Thus, it is obvious that part of the strange production flux will come from first producing a πN intermediate state which subsequently decays into the KY system. A suitable method to account for these processes, as well for the final state interactions, is to consider a coupled channel formalism which includes the most relevant opened channels in the considered regime.

Studying the effects of coupled channels is however an involved task due to the many intermediate and final state channels which are active. Thus, we need to have reasonable models for the following mechanisms: $\gamma N \to \pi N$, $\pi N \to \pi N$, $\pi N \to KY$ and $KY \to KY$ in the considered total center-of-mass energy regime, $W \approx 1.6 - 2.7$ GeV. The main sources utilized in this work are Ref. [14] for πN and Ref. [7] with a number of improvements in the formulation for the KY hadronic channels.

The procedure employed [7] to fit the parameters involved in the model has been to first fix the meson-baryon model parameters performing a χ^2 fit to the available $\pi N \to KY$ data. Then the photoproduction process has been studied keeping the meson-baryon part unaltered.

The direct $K\Lambda$ photoproduction process is handled using the quark model of Refs. [9, 10]. That approach allows one to include all 3 and 4 star resonances and contains one adjustable parameter per resonance with masses below 2 GeV, due to the $SU(6) \otimes O(3)$ symmetry breaking.

A detailed description of the formalism will be published elsewhere [11].

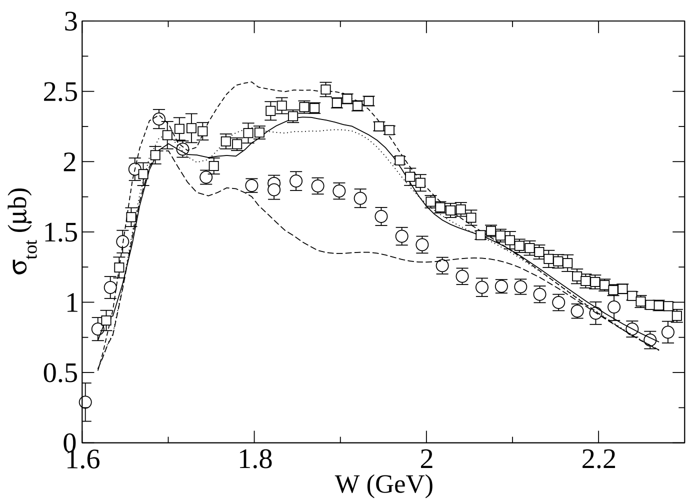

Figure 1. Total cross section as a function of the centre of mass energy. Solid curve corresponds to the full model, dotted, dashed and long dashed correspond to switching off the $3^{rd}P_{13}$, $3^{rd}S_{11}$ and $3^{rd}D13$ resonances, respectively. Circle symbols, are SAPHIR data, Ref. 3. Square symbols correspond to the data from CLAS [1].

3. Results

The present experimental status is the following: there are two quite complete measurements of the differential cross section performed at CLAS [1] and SAPHIR [3]. The most recent CLAS data [1] for differential cross sections shows a closer agreement to SAPHIR data than those released [2] previously. Secondly there are measured data for recoil polarization asymmetry from CLAS [2] and also polarized photon asymmetry measured at LEPS [5].

We have performed a thorough study of the compelete database [11]. Fitting separately SAPHIR and CLAS data, leads to reduced χ^2 of 1.3 and 2.1, respectively. Then, fitting *simultaneously* all cross section and polarization asymmetry data, we get $\chi^2_{d.o.f} \approx 3$.

In fig. 1 the total cross section predicted by this model is compared to the data. To study the role played by new resonances introduced, we also show results obtained by switching off those resonances one by one, without further fittings. Here, we emphasize that discrepencies between the two data sets are much smaller in the differential cross sections than in the total cross sections shown here. Larger discrepencies in the latter

case are very likely due to the angular range covered by each data set and extrapolation methods used to extract the total from the differential cross sections.

The figure summarizes our main findings which are to be presented in a longer discussion [11]: the full model allows for a good reproduction of the data, the possible influence of the $3^{rd}P_{13}$ is very minor, and finally the role played by $3^{rd}S_{11}$ and $3^{rd}D_{13}$ are sizable. The mass and width of these resonances in this model are : S_{11} [M=1.84 GeV, Γ=283 MeV] and D_{13}[M=1.93 GeV, Γ=252 MeV]. These findings are in line with other studied with respect to the manifestations of a new S_{11}, Ref. [10], and a new D_{13}, Ref. [15], resonances.

References

1. R. Bradford *et al.*, arXiv:nucl-ex/0509033; R. Schumacher, private communication (2005).
2. J.W.C. McNabb *et al.*, Phys. Rev. C **69**, 042201 (2004); J.W.C. McNabb, PhD Thesis, CMU (2002); R. Schumacher, private communication (2003).
3. K.H. Glander *et al.*, Eur. Phys. J. A **19**, 251 (2004).
4. R. Lawall *et al.*, Eur. Phys. J. A **24**, 275 (2005).
5. R.G.T. Zegers *et al.*, Phys. Rev. Lett. **91**, 092001 (2003).
6. W.-T. Chiang, F. Tabakin, T.-S. H. Lee, B. Saghai, Phys. Lett. B **517**, 101 (2001).
7. W.-T. Chiang, B. Saghai, F. Tabakin, T.-S. H. Lee, Phys. Rev. C **69**, 065208 (2004).
8. B. Juliá-Díaz, *et al.*, Nucl. Phys. A **755**, 463 (2005).
9. Z. Li, Phys. Rev. C **52**, 1648 (1995).
10. B. Saghai and Z. Li, Eur. Phys. J. A **11**, 217 (2001).
11. B. Juliá-Díaz, *et al.*, to be submitted to Phys. Rev. C.
12. See e.g. S. Capstick, W. Roberts, Prog. Part. Nucl. Phys. **45**, 5241 (2000).
13. V. D. Burkert and T. S. H. Lee, Int. J. Mod. Phys. E **13**, 1035 (2004).
14. T. Sato and T.-S. H. Lee, Phys. Rev. C **54**, 2660 (1996); Phys. Rev. C**63**, 055201 (2001).
15. A.V. Sarantsev *et al.*, Eur. Phys. J. A **25**, 441 (2005); T. Corthals *et al.*, arXiv:nucl-th/0510056.